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June 13, 2011

Ms. Melissa Taylor
United States EPA
Region 1, New England
Five Post Office Square, Suite 100
Mail Code: OSSR07-4
Boston, Massachusetts 02109

Subject: Response to the Review of Further Vapor Intrusion Assessment dated May 18, 2011, Nuclear Metals, Inc. Superfund Site, Concord, Massachusetts

Dear Ms. Taylor:

Our responses to the Review of Further Vapor Intrusion Assessment by EPA dated May 18, 2011 are provided in Attachment 1 to this letter. If needed, we can discuss the proposed approach. I will contact the property owner for access once we have an agreed scope of work.

Please contact me if you have any questions.

Sincerely,

Bruce Thompson
Project Coordinator

cc: Garry Waldeck, MassDEP
Respondents
Todd Creamer, Geosyntec Consultants

Encl: Attachment 1 – Response to Agency Comments

Attachment 1- Response to Comments

Geosyntec consultants

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Memorandum

Date: 27 May 2011

To: Bruce Thompson, de maximis, inc.

From: Todd Creamer, Geosyntec Consultants, Inc.

Subject: Response to USEPA Comments on 07 April 2011 Scope of Work
Further Vapor Intrusion Assessment at 2250 Main Street
NMI Superfund Site, Concord, Massachusetts

This memorandum summarizes Geosyntec's response to the USEPA's 18 May 2011 comments on the proposed scope of work and estimated cost to conduct environmental sampling in support of an off-site vapor intrusion investigation at 2250 Main Street (the structure) in Concord, Massachusetts, in a memorandum dated 07 April 2011.

USEPA comment #1

> It is recommended that the indoor air and soil gas samples proposed be collected from the location of the highest concentration collected in the previous investigation (mechanical room). In addition, one indoor air sample (and a duplicate at the same location) may not be sufficient to adequately characterize spatial variability throughout the lower level. Though each occupied space does not need to be sampled, it is necessary to sample more than one location to provide representative data to evaluate exposures. Specifically, a location within or near the second floor residence will be necessary to evaluate residential air exposures. Alternatively, if no sampling is performed at the residential level, and indoor air and sub slab soil gas results from the lower level are above residential screening levels, a full VI study may need to be performed, EPA may require: 1) periodic monitoring of sub slab soil gas indoor air and documentation and reporting regarding building floors and any operational changes; and 2) an environmental deed restriction until concentrations of VOCs are within risk-based levels.

Response to comment #1 – number and locations of samples

With the building owner's consent for access, Geosyntec proposes to collect two (2) indoor air samples from the lowest level of the structure, one in the mechanical room, and one near the center of the structure near the base of the stairwell. One (1) sub-slab soil gas sample will be collected from the mechanical room immediately following collection of indoor air samples.

More than one sub-slab soil gas sample is unnecessary because previous studies conducted over multiple seasons have demonstrated that spatial variability of target analyte concentrations is very low. An indoor air sample in the second floor will not be collected at this time. If trichloroethene (TCE) concentrations in indoor air samples from the lowest level exceed concentrations of TCE in outdoor air and they exceed the USEPA residential Regional Screening Level (RSL) of 1.2 μg/m3, then sampling of the second floor residential level will be considered.

USEPA comment #2

> Because these data may be used for potential residential exposures within the building, a 24-hour sampling period is recommended to provide more representative data than the proposed 8-hour period, considered adequate for commercial exposures. Please address.

Response to comment #2 – indoor air sample duration

With the building owner's consent for access, Geosyntec proposes to use quantitative passive diffusion samplers instead of SUMMA™ canisters to sample indoor air and outdoor air over a period of approximately one week. According to Dr. Henry Schuver (2009) of the USEPA's Office of Solid Waste and Emergency Response, decades of studies on the migration of radon gas from the subsurface to indoor air have shown that longer duration indoor air samples (e.g., weeks to months) better represent the long term average indoor radon concentration than short duration samples (e.g., hours to days) by reducing the observed temporal variability (please see attached presentation). Therefore longer duration samples are more likely to produce meaningful data for multi-year exposure scenarios for building occupants than shorter duration samples. The Waterloo Membrane Sampler™ (WMS™) is ideally suited to this application because it is commercially available from Air Toxics, LTD, has undergone extensive testing in the field and laboratory and has shown excellent agreement with the "gold standard" SUMMA™ canisters and USEPA's TAGA bus samples over a very wide range of concentrations (see attached brochure). WMS™ are also advantageous because they are very small and unobtrusive, and in this case, the building owner is already reluctant to allow sampling, especially with the much larger SUMMA™ canisters.

USEPA comment #3

> The residential RSL for TCE is 1.2 ug/m3. The proposed reporting limit of approximately 0.5 ug/m3 is marginally acceptable being only 2-fold less than the RSL, when it is EPA's recommendation that reporting limits be at least 3 to 5-fold lower than the comparison criteria. Please address by providing additional justification for the proposed very limited reporting of VOCs in indoor air and further justify that the approximate 0.5 ug/m3 reporting limit will achieve project objectives.

Response to comment #3 – analyte list and analytical reporting limits

Sub-slab soil gas and outdoor air data from 2009 and 2010 were analyzed for three compounds, TCE, tetrachloroethene and vinyl chloride following review of analytical results from samples collected in nearby groundwater monitoring wells. For the target analytes, groundwater is the only source that is the subject of this vapor intrusion investigation. However, consumer products can act as sources of all three compounds, confounding efforts to discern the origin of these compounds if detected in indoor air. Because only TCE was detected in sub-slab soil gas over both previous sampling events, the analyte list can be narrowed to TCE.

A WMS™ analyzed by thermal desorption can achieve a TCE reporting limit of 0.25 $\mu g/m^3$ when deployed for a period of approximately 4.5 days (a reporting limit which is 4.8 times lower than the RSL for TCE). Longer deployment achieves lower reporting limits. The result is defensibly quantitative because the rate of TCE uptake by the sampler is very well known and has been empirically determined in the laboratory in an atmosphere of known concentration. Air Toxics performs the GC/MS analyses with the full quality assurance and quality control of whole gas samples.

USEPA comment #4

> Please address why Tier I instead of Tier II data validation is being performed.

Response to comment #4 – data validation

Geosyntec will perform Tier II validation on the indoor air, outdoor air and sub-slab soil gas data collected for this study.

USEPA comment #5

> A second round of sampling during the colder months when heating systems are active will be necessary because this sampling event will likely be performed during what might be considered non-worst-case conditions (i.e., outside the cold months and after the high groundwater period.) Please address.

Response to comment #5 – sampling to address temporal variability

With the building owner’s consent for access, Geosyntec proposes to collect a second round of two (2) indoor air samples and one (1) outdoor air sample by WMS™, and one (1) sub-slab soil gas sample in the mechanical room by SUMMA™ canister. The second round will be collected during the heating season. It is notable that sub-slab soil gas samples collected during 2009 and 2010 showed that the temporal (seasonal) variability in TCE concentration was very low. The minimum and maximum concentrations of TCE measured in sub-slab soil gas differed only by a factor of approximately four (6.5 and 29 $\mu g/m^3$, respectively), and by a factor of just three or less when comparing the same sub-slab sampling locations (29 and 20 $\mu g/m^3$ at SS-1; 19 and 6.5 $\mu g/m^3$ at SS-2). Accordingly, and unless there is an indoor source of TCE, we anticipate similar results for both upcoming sampling events.

USEPA comment #6

> For completeness, please provide details on the location and height for the outdoor air sample location.

Response to comment #6 – outdoor air sample details

The outdoor air sampling location will be the same as was used during both previous sampling events in 2009 and 2010. SUMMA™ canisters were placed on top of a stone wall bordering an outdoor stairway between the upper and lower parking lots adjacent to 2250 Main Street on the west side of the structure. The sample intake was approximately three feet above the highest adjacent ground surface. A WMS™ will be hung in approximately the same location for a period equal to the sampling period used for indoor air.

* * * * *

Investigating Vapor Intrusion with Confidence and Efficiency: Observations from Indoor Air Radon

Air & Waste Management Assoc.
Vapor Intrusion Specialty Conference
San Diego, CA
Jan. 28, 2009

Presented by:
Henry Schuver, DrPH,
USEPA* – Office of Solid Waste
See: http://iavi.rti.org & www.envirogroup.com/vaporintrusion

*includes personal observations that do not imply EPA policies

Dominant Features of VI Pathway

- Uncertainty
  - Lack of knowledge
    - Reducible (in theory; e.g., intervening geology)
- Variability
  - Known to vary (range of *y*), but is unpredictable
    - Irreducible (e.g., pressure differences in subslab-indoor)
    - Need statistics (populations of data) to describe - historical
  - Temporal (variation Across Time)
  - Spatial (variation Across Space)

The USEPA's Current Approach ('Roadmap')

- 8 Spokes
  - Brownfields VI Primer
    http://www.brownfieldstsc.org
  - 2002 draft VI Guidance
  - ITRC VI "Practical Guide" (vol. 1)
    - VI Database (doc. & data) draft @ http://iavi.rti.org
    - Background Indoor Air Concentrations (to public soon)
    - Conceptual Site Models (to public soon)
  - VI in Non-Residential Settings
  - TCE & VI Memorandum
- Hub – "Roadmap"

EPA is Continuing to Work on VI

- To keep pace with evolving understanding:
  - EPA is Continuing the Dialogue with:
    - federal partners
    - state regulators
    - industry
    - academia
    - environmental groups, and
    - general public;
  - And is dedicated to improving the "*confidence & efficiency*" of vapor intrusion ***prevention***

Final Thoughts…

Dr. Paul Johnson's slide from March 2008 AEHS, San Diego

1. **There is a lot of good work taking place - in particular with respect to trying to communicate the data we have and how it might be used. The number of "experts" and knowledge available has increased.**
2. **The evolution of pathway assessment guidance is a logical incremental extension of past work and the historical conceptual model - and probably what is right for now.**
3. **We <u>should be thinking ahead</u> to what it takes to <u>increase confidence and efficiency</u> - we may have <u>already reached our limit</u> on those for the historical <u>MLE-based</u> pathway assessment model.**
4. **<u>Data collection</u> (e.g., soil gas, groundwater sampling, etc.) is <u>still an overall weakness</u>, as well as the skill to <u>evaluate</u> the data (e.g., consistency, <u>what can</u> and cannot <u>be concluded</u>, etc.)**
5. **The <u>sharing of data and experiences is invaluable</u> to pathway assessment guidance evolution**

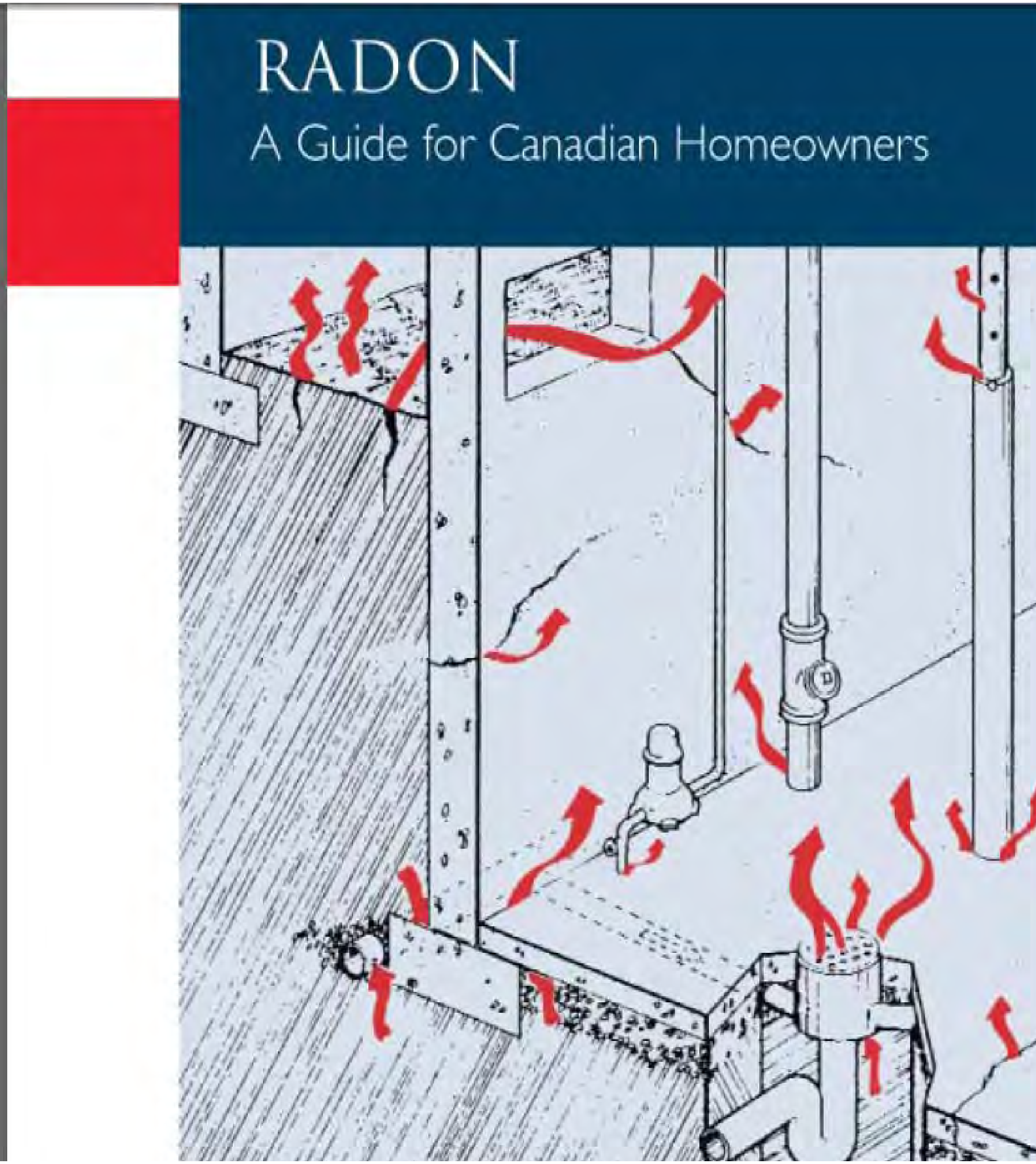
Investigating Vapor Intrusion with Confidence and Efficiency:

- Radon intrusion is analogous to chemical Vapor Intrusion (VI) (Mosley 2004; Mosley 2007, McHugh 2008)
  - – Long history of Radon studies
    - >30 yrs of global effort
    - 1000s of researchers & papers

    - Needed to break the topic into several categories:

    - **1) *External*-based Studies**
    - **2) *Indoor* Air-based Studies**
    - **3) *Health* Outcome-based Studies**

Radon workers are ahead of us



<u>External</u>-based **Radon** Studies Overview

- Despite initial presumptions of predictability based on external data ('85)

- > 20 yrs later:

  – We are continuing to study and model the
  – "<u>great number of parameters and processes</u>"
  – affecting radon in indoor air (Font 2003)

VI Factors studied 1

Factor	**Radon VI Ref.***	***Chemical VI Ref.***
• Diffusion-based transport	Tanner 1964	
• **Energy conservation**, reduced ventilation	Budnitz 1979	
• Radium (source) Concentration & Distribution, Soil:	Tanner 1980	
• Porosity, Permeability, Moisture, Meteorological	Tanner 1980	
• **Rainfall & surface saturation capping effect**	Schery 1984	
• Crawlspaces (>50% enters house)	Nazaroff 1985	
• Convective-based transport	Sextro 1987	
• Building Construction, Stack Effect, Wind	Nazaroff 1987,88	
• Season	Borak 1989	*Kuehster 2004*
• Soil Temperature	Washington 1990	
• Heavy rain	Mose 1991	*Lundegard 2008*
Convective air flow in **Karst** geology	Wilson 1991	
• Depth to (chemical) Source	Johnson 1991	
• Modifications in Bldg. structure	Steck 1992	
• Minor modifications to heating systems	Steck 1992	
• Heat distrib. Type	Klotz, 1993	
• Bldg. Age (of construction)	Klotz, 1993	
• Soil classification, Bedrock type, Water table depth	Steck 1996	
• Bldg Basement or not	Price 1996	
• **Rate-of-change** in Atmospheric Press. Fluctuations	Robinson 1997	

VI Factors studied 2

Factor	Radon VI Ref.*	*Chemical VI Ref.*
Atmospheric Press. Fluctuations & Soil Properties	Robinson 1997	
Soil response time, Soil capacitance	Robinson 1997	
Bldg Heating type: fire or elec.	Mose 1997	
Bldg. Concrete poured or block, **home use patterns**	Mose 1997	
Living Habits	Miles 1998	
Independent heat (vs. shared apt.)	Gallelli 1998	
Type of **window frames & # panes**, Bldg. Story level	Gallelli 1998	
Local geology, Superficial cover	Miles 1998	
Air/barometric pressure, **wind direction**	Riley 1999	
Fluctuation in wind **direction**, Wind speed	Riley 1999	
Fluctuation in wind **speed**, Wind (loading)	Riley 1999	
HVAC/Ventilation systems (installed, & operations)	Riley 1999	
Combined Surface Geology, Topo. & Wind Direction	Keskikuru 2000	
Soil-gas pressure (wind induced)	Keskikuru 2000	
Indoor-Attic space	Keskikuru 2000	
Soil-indoor pressure difference	Font 2001	
Frozen soil as cover (temp. & water)	Winkler 2001	*Mickunas 2007*
Saturated soil as cover (Summer)	Winkler 2001	
Sunshine duration, Snow cover, **fuel prices** (insulation)	Papp 2001	

VI Factors studied 3

	Radon VI Ref.*	*Chemical VI Ref.*
• Outdoor air **temperature** (alone)	Marley 2001	
• Water vapour pressure	Marley 2001	
• Maximum variation Outdoor Temperature	Rowe 2002	*Lundegard '08*
• Weather fronts, Occupied bldg or not	Rowe 2002	
• Substructure type, Cellar ventilation	Wang 2002	
• Increased Energy Efficiency	Darby 2005	
• **Building as cover** (capping **flux**)		*Abreu 2005*
• Building as cover (**decreased moisture underneath**)		*Tillman 2007*
• Stable **rural vs. recently urbanized**	Zunic 2007	
• Combined effects of contrast in Outdoor & Soil Air …		
• Temperature (Gas density-driven flow) in setting w/ …		
• coarse surface geology & terrain elevation	Sundal 2008	
• Chemical properties, Degradation (bio+)		*Lundegard '08*
• Oxygen content, Oxygen & Distance		*Lundegard '08*

External-based Studies

- Can ***not*** represent:

- 1) the influence of building factors
  - – e.g., open staircases to upper floors (Makelainen 2001)
  - – e.g., modest structural changes (Steck 2007)
- 2) the interaction of the building with meteorology (the entry driving forces)
- 3) the influence of occupant behaviors
  - – e.g., sleeping with windows open (Makelainen 2001)
    - » Also, Mose (1997), Miles (1998), Krewski (2005)

Steck 2007

American Association of Radon Scientists and Technologists 2007 Proceedings
Of the 2007 AARST International Symposium Jacksonville, FL, 2008©AARST

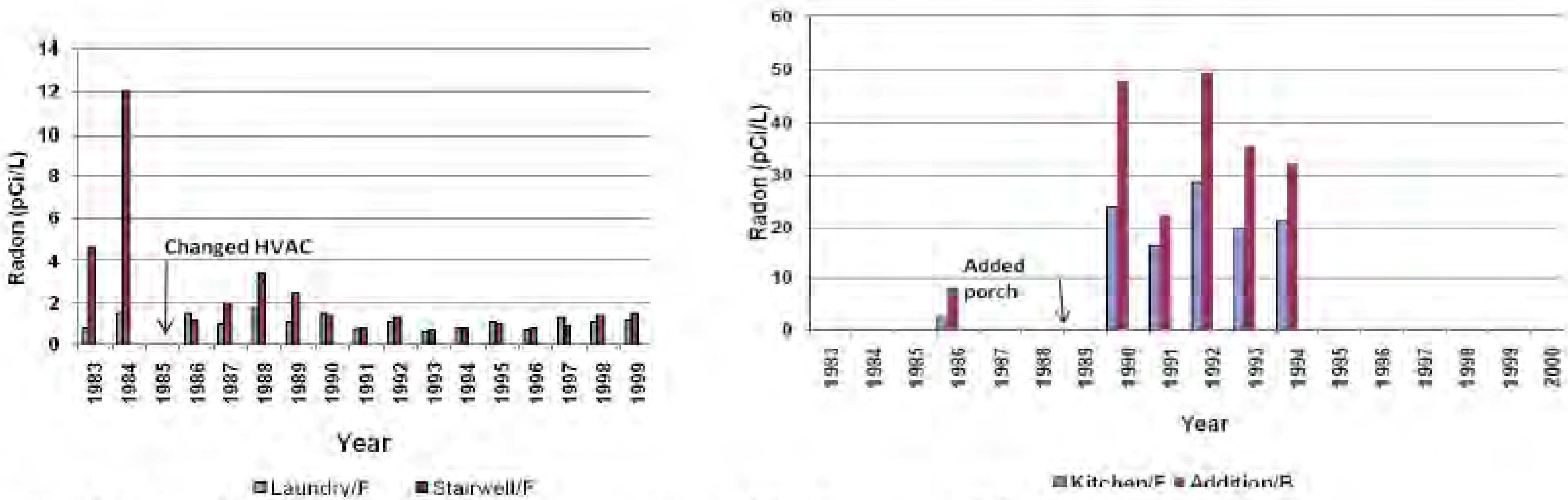


Figure 4 Examples of large radon changes created by house modifications

http://www.aarst.org/proceedings/2007/8-SteckYTYRnvariation07.pdf

After 30 yrs of study **External**-based Approaches:

- Have <u>only</u> been able to provide the "<u>radon potential</u>" for an area, e.g.,

  »

  – **2009 Kitto & Green** (radon potential maps)
    - <u>**Percentage**</u> of **homes** <u>expected to **exceed**</u> the <u>**screening**</u> level

- Have <u>**NOT**</u> been found to provide reliable <u>**quantitative**</u> estimates for <u>individual</u> buildings

Conclusion from 30 yrs of Study

- When assessing indoor levels (#) in **individual** buildings:
  - Radon intrusion studies have only reinforced the advantages and **necessity** of testing **indoor air**
    - e.g., look to EPA's experiences

1991 EPA

- Despite initial presumptions & >5 yrs of intensive study:

- EPA's Office of Research and Development (ORD) reported:

  – "Several studies have <u>attempted</u> to make <u>simple correlations</u> between <u>radon [gas]</u> or radium concentrations in the soil and <u>indoor</u> radon concentrations ...

  – <u>**no significant correlations**</u> were made between these variables."

2009 EPA

- While academic studies using external measures continue across the globe;
- After approximately 30 years of study and the collection of approximately 18 million measurements of indoor radon across the US
  - the EPA Radon Web site (www.epa.gov/radon), and the US Surgeon General, continue to recommend (since 1994):
  - that **individual** homes be **tested** for radon
  - [not predicted from outside measurements, since reliable predictive methods have not yet been found]

<u>Indoor Air</u>-based Studies

Sample of Indoor Air Studies

- 1991Martz et al.
- 1992 Steck
- 1994 White et al.
- 1996 Hubbard, Mellander & Swedjemark
- 2001 Miles
- 2001 Makelainen, Arvela, Voutilainen
- 2002 Rowe, Kelly and Price
- 2003 Chen
- 2003 Dolejs & Hulka 2003
- 2004 Steck, Dumm, & Patton
- 2004 Karpinska, Mnich and Kapala
- 2005 Karpinska et al.
- 2005 Krewski et al.
- 2006 Groves-Kirkby et al.
- 2007 Denman et al.
- 2007 Zhang et al.
- 2007 Steck
- 2009 Steck
- 2009 Folkes et al. (chemicals)

Indoor Air Integrates:

- Influence of:
  - Sub-surface environ. factors and source
  - Above-ground environmental factors
  - Building factors
- **Variability** in indoor air reflects **variability** in:
  - Sub-surface environ. factors and source
  - Above-ground environmental factors
  - Building factors

Steck ≤ 2004*

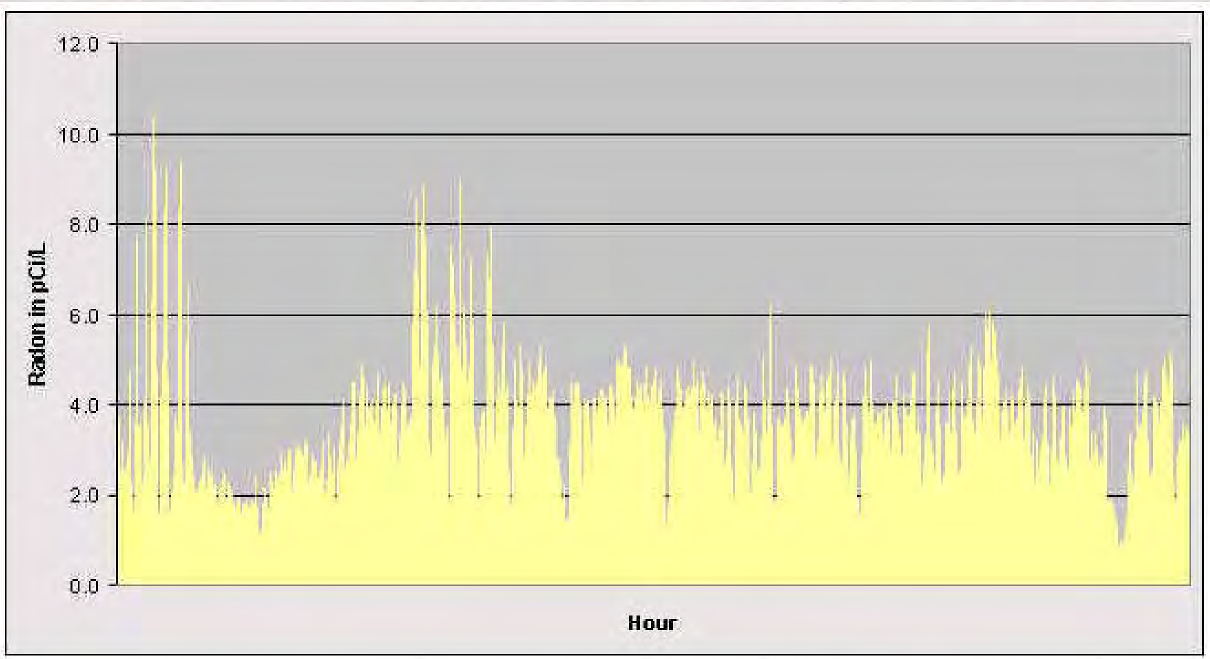
http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Indoor radon variation with time and location

concentration in your home? That depends on which room you measure and what time that you measure. If you are interested in radon because of its health risk, you should ma
ie rooms that are frequently occupied by people.

Hour-to-hour

f the hourly average radon in a house from the beginning of January to the end of March 1995. Note that the average radon concentration ranged from a high of 10 pCi/L to less
verage over the period was 3.8 pCi/L. That's why a measurement that lasts only a few hours can give such a false reading of the long term average.



* Last update to website

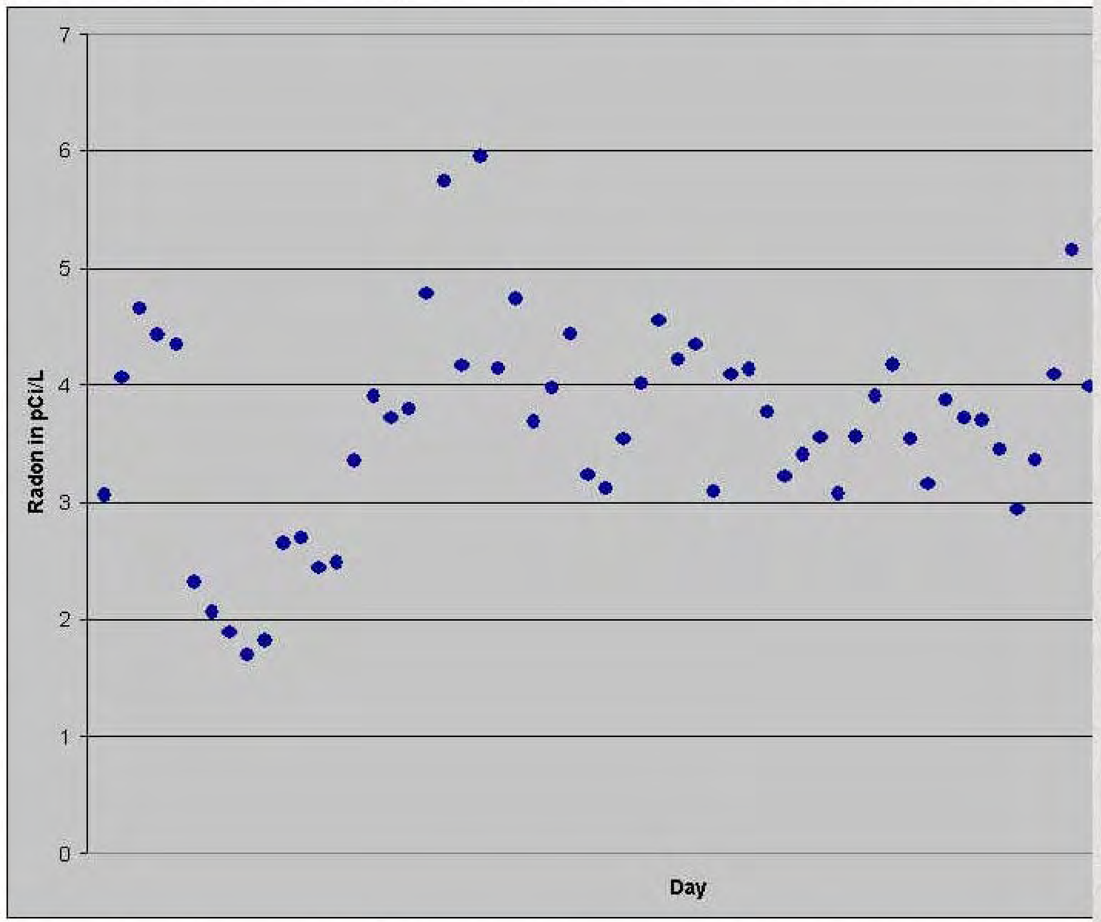
Steck ≤ 2004

http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

2-Day

Day-to-day

Here is a graph of the average radon in a house for each 2 day (48 hour) period from the beginning of January to the end of March 1995. Note that the average radon concentration ranged from a high of 6 pCi/L to about 1 pCi/L. The true average over the period was 3.8 pCi/L. That's why a measurement that lasts only a two days can give a false reading of the long term average.

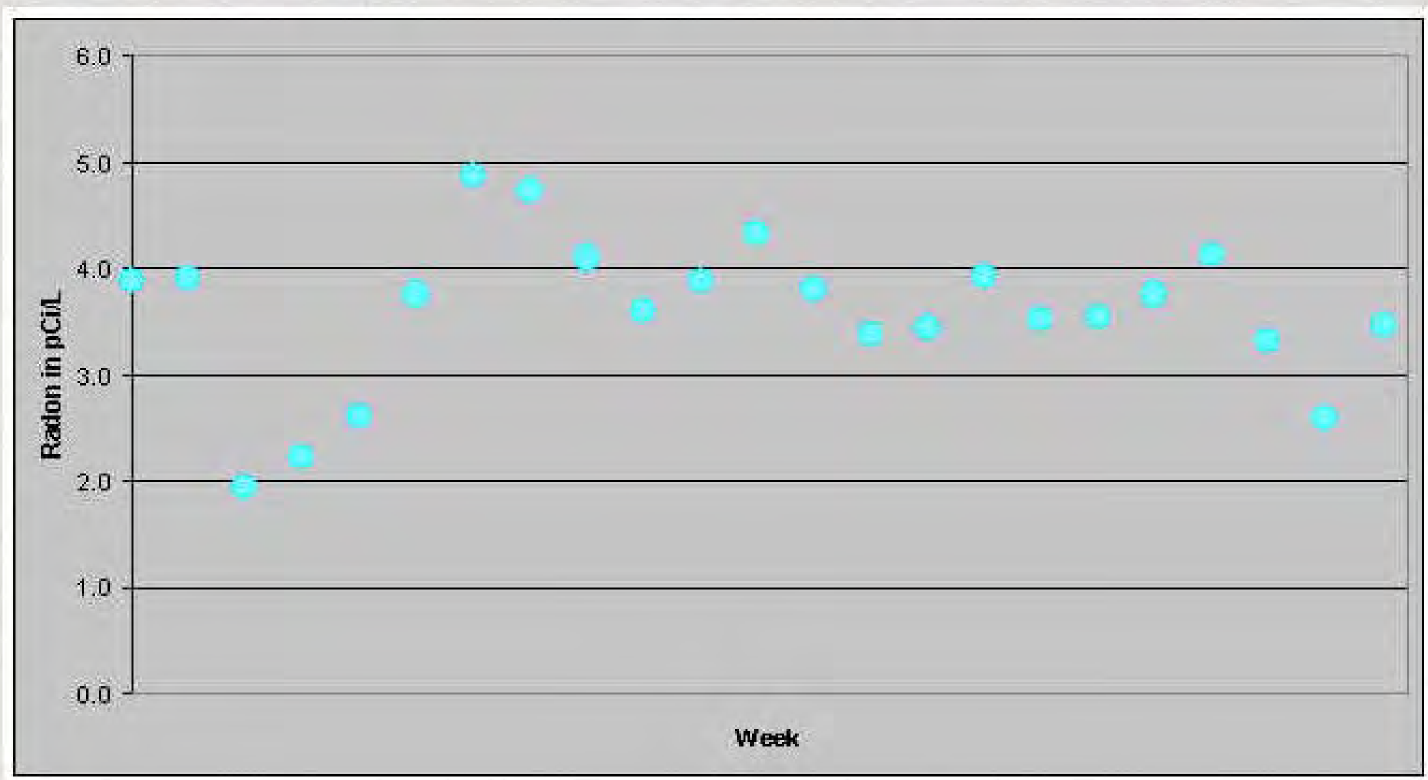


Steck ≤ 2004

http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Week to week

rage radon in a house for each weekly period from the beginning of January to the end of March 1995. Note that the average radon concentration ran
verage over the period was 3.8 pCi/L. Even a week long measurement can be quite far from the long-term average.

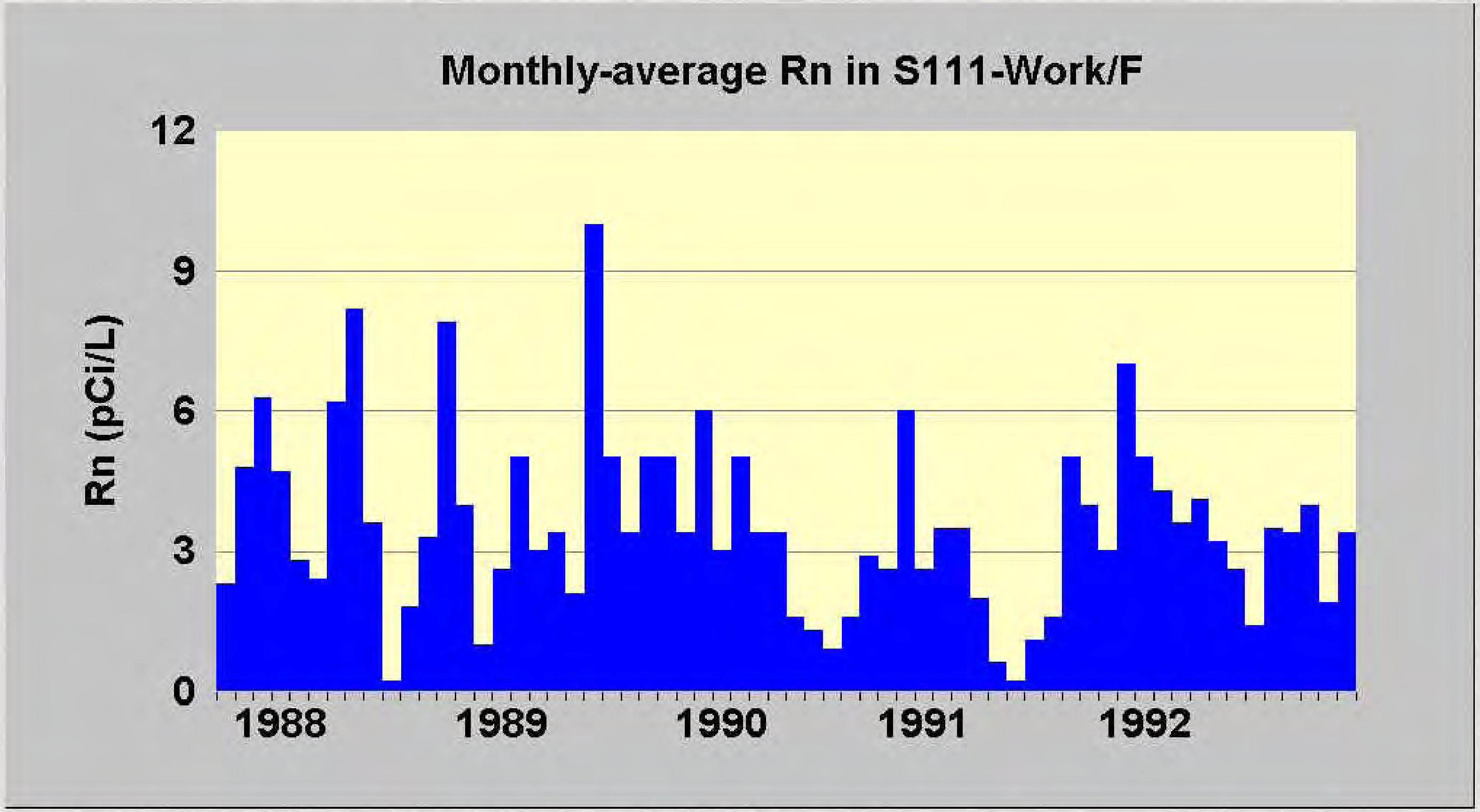


Steck $\leq$ 2004

http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Month-to-month

Here is a graph of the monthly average radon in a house for the period from the beginning of January 1988 to January 1993. Note that the average radon concentration ranged from a high of 10 pCi/L to less than 1 pCi/L. The true average over the period was 3.5 pCi/L. Even a month-long measurement can be quite far from the long-term average.



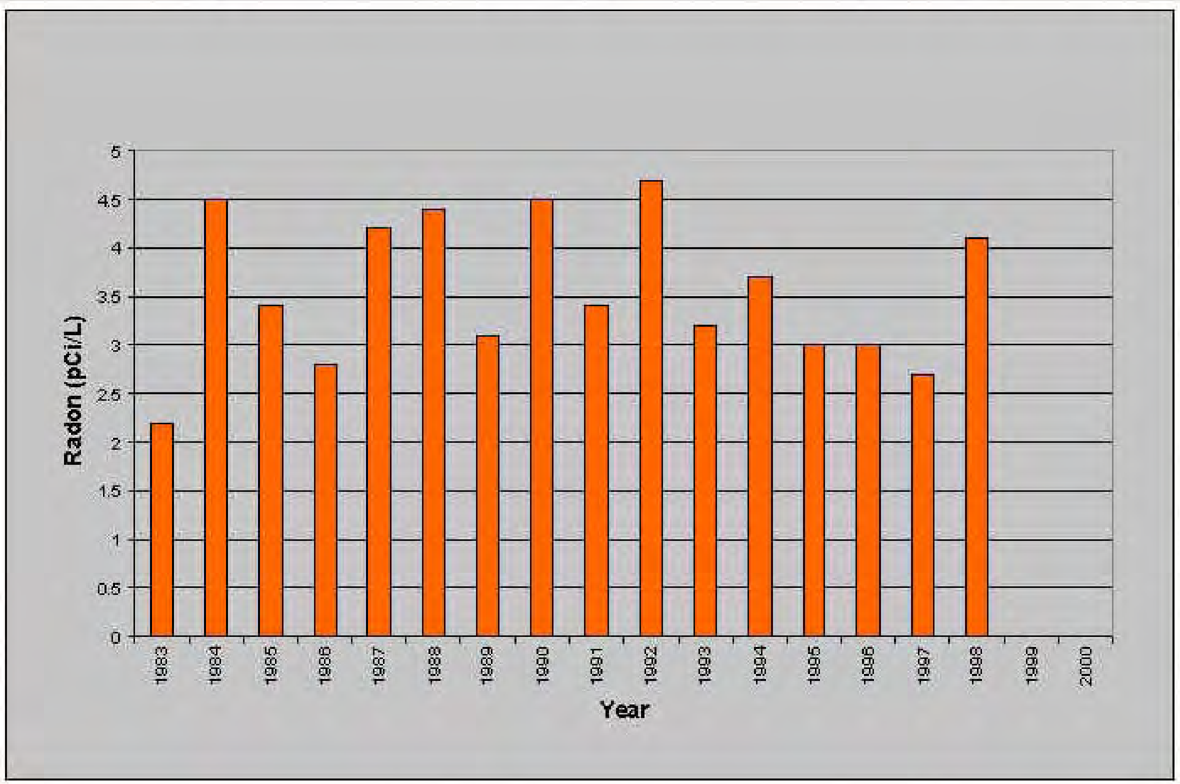
If you analyze this graph for seasonal variation, you will find the highest readings in spring and fall, with summer being the lowest. Spring and fall are seasons of active weather at this site that often requires that the house be closed and heated. heating

Steck ≤ 2004

http://www.csbsju.edu/MNradon/indoor_radon_variation_over_time.htm

Year-to-year

is a graph of the annual average radon in a house for each yearly period from the 1983 to 1998. The house was built in 1981 so this is a fairly complete history. Note that the yearly average r
entration ranged from a high of 4.6 pCi/L to a low of 2.2 pCi/L. The true average over the period was 3.55 pCi/L. In a study of 100 Minnesota homes, I have found that the year-to-year va
ical Minnesota house is about 25%. This means that a one year test should be sufficient to decide whether to mitigate or not if you take the view that your lung cancer risk is proportional to the
radon concentration. However, if you take the current EPA view that there is a sharp "take-action threshold" at 4 pCi/L, you may get a false reading from a single year-long measurement. A
ion means that near the current action level of 4 pCi/L, a single year-long measurement might easily yeild any value from 3 pCi/L to 5 pCi/L when the true average is 4pCi/L.



Summary of Radon Conc. (pCi/L) Steck $\leq$ 2004 (Minn.)

Sample	Factor	M-M Range	Avg.	Period
Hour	10x	<1 to 10	3.8	1st 3 mo. '95
2-Day	6x	1 to 6	3.8	1st 3 mo. '95
Week	2.5x	2 to 5	3.8	1st 3 mo. '95
Month	10x	<1 to 10	3.5	6 yr. '88-93
Year	2.1x	2.2 to 4.6	3.55	15 yr. '83-98

- Yr. Avg. from 100 homes vary 25% (e.g., 4 ~ 3 to 5 (+/- 1) pCi/L)

STUDIES ON TEMPORAL VARIATIONS OF RADON IN SWEDISH SINGLE-FAMILY HOUSES

Lynn Marie Hubbard, Hans Mellander, and Gun Astri Swedjemark
Swedish Radiation Protection Institute, S-171 16 Stockholm, Sweden

Environment International, Vol. 22, Suppl. 1, pp. S715–S722, 1996

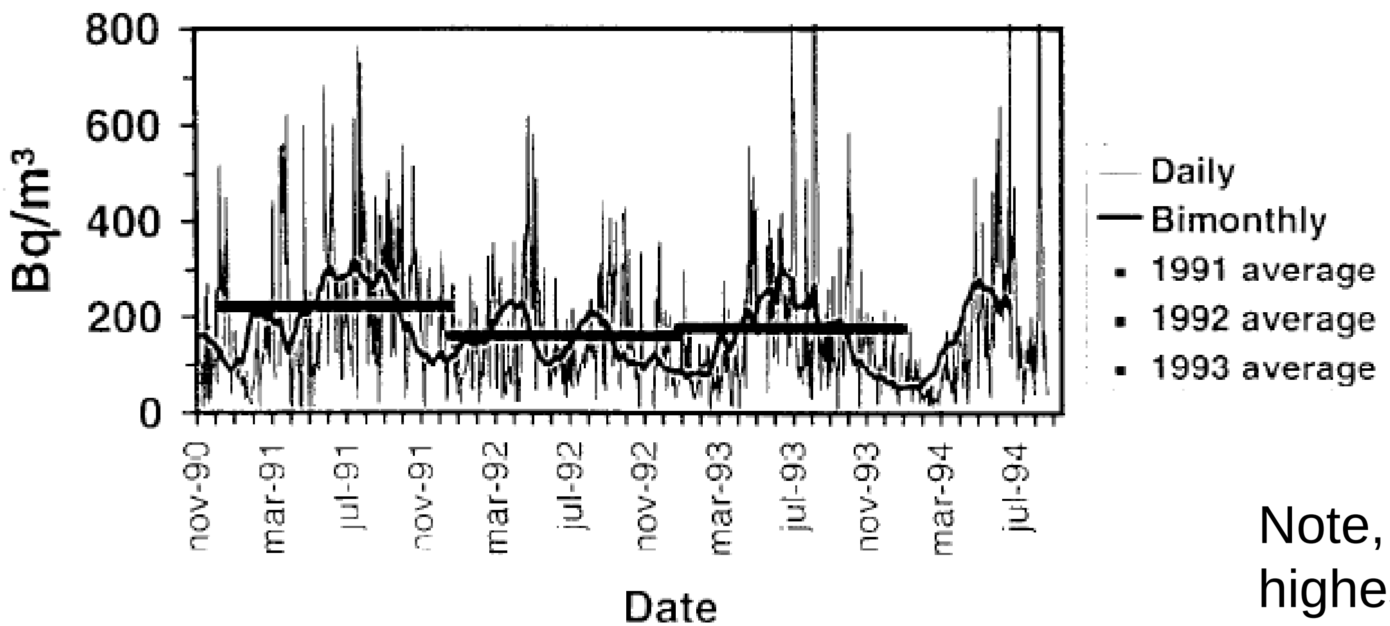


Fig. 1. Daily, bimonthly, and yearly averaged indoor radon concentration.

Note, highest in spring & fall

Summary of Radon Conc. (Bq/m^3) Hubbard et al. 1996 (Sweden)

Sample	Factor	Range	Avg.	Period
1-Day	80x	<10 to 800	yr.	4 yr. ’90-94
2-Week	4.3x	70 to 300	yr.	4 yr. ’90-94
Year	1.3x	180 to 230	-	4 yr. ’90-94

- ~ four year period Nov. 1990 – July 1994

Folkes et al., 2009
1-Day (from chemicals)

- Using 715 indoor air samples of 1,1-DCE collected over <u>**24-hrs**</u> found variations to range from 45 unmitigated (low conc.) homes from quarterly to annual frequencies for 2 to 10 years
  - "The [indoor air] normalized [by property annual average conc.] values ranged [max.-min.] from about <u>10%</u> … to about <u>ten times</u> the annual average of the home"
    - 100% of samples w/n +/- 10x of the home's annual mean
    - 95%
    - 68% of samples w/n +/- 2 to 3x of the homes annual mean
  - "Short term variability can overwhelm any seasonal trend" [very similar to comment by Rowe '02]

Multiple (2-Day) Sample Events White et al. (1994)

- Collected measurements of indoor radon in 480 houses in 11 states for over one year:
  - Relative to a concurrent one-year measurement (for a Annual Living Area Average (ALAA)) they found:

Events	95% CI	Comp. Period		Example
1 season	+/-2.5x	ALAA	1 yr	If 100 Bq/m^3; 95% CI = **40-250**
2 seasons	+/-2.2x	ALAA	1 yr	If 100 Bq/m^3; 95% CI = **45-220**
4 seasons	+/-2.0x	ALAA	1 yr	If 100 Bq/m^3; 95% CI = **50-200**

Repeated Measurements

USEPA 1994

- "After extensive research and review by its science advisory board (**SAB**)… EPA recognizes that **short-term tests** [e.g., 2 to 7 days] can **<u>not</u>** always <u>predict</u> the <u>average</u> radon level in a home; however,

- more than <u>90 percent</u> of the time

- **<u>two</u>** [i.e., repeated] short-term measurements in the living area <u>can predict</u> [i.e., screen] whether a home's <u>annual average</u> <u>is **above four [4]**</u> <u>pCi/L</u> [148 Bq/m^3]"

RESIDENTIAL RADON RISK ASSESSMENT: HOW WELL IS IT WORKING IN A HIGH RADON REGION?

International Radon Symposium, San Diego, Sept. 2005

Daniel J. Steck
Physics Department, St. John's University
Collegeville, MN 56321 USA

http://www.aarst.org/proceedings/2005/2005_12_Residential_Radon_Risk_Assessment_How_Well_Is_It_Working_In_A_High_Radon_Region.pdf

ABSTRACT

Three surveys of long-term indoor radon concentrations in Minnesota living spaces show that the state has many homes with elevated radon. A large random sample of Minnesota homes had a geometric mean of 3.5 pCi/L. Forty two percent had radon concentrations above 4pCi/L. A comparative study of short term and long term radon measurements in a subsample of these homes show poor correlation between short-term and long-term indoor radon concentrations as a result of significant temporal variation over the different measurement intervals. This poor correlation yields a significant failure rate when the current diagnostic testing protocol is used to select an appropriate action. When measurement errors are combined with some homeowner's failure to follow the mitigation decision protocol, the current radon assessment procedure fails in many homes.

Steck 2005

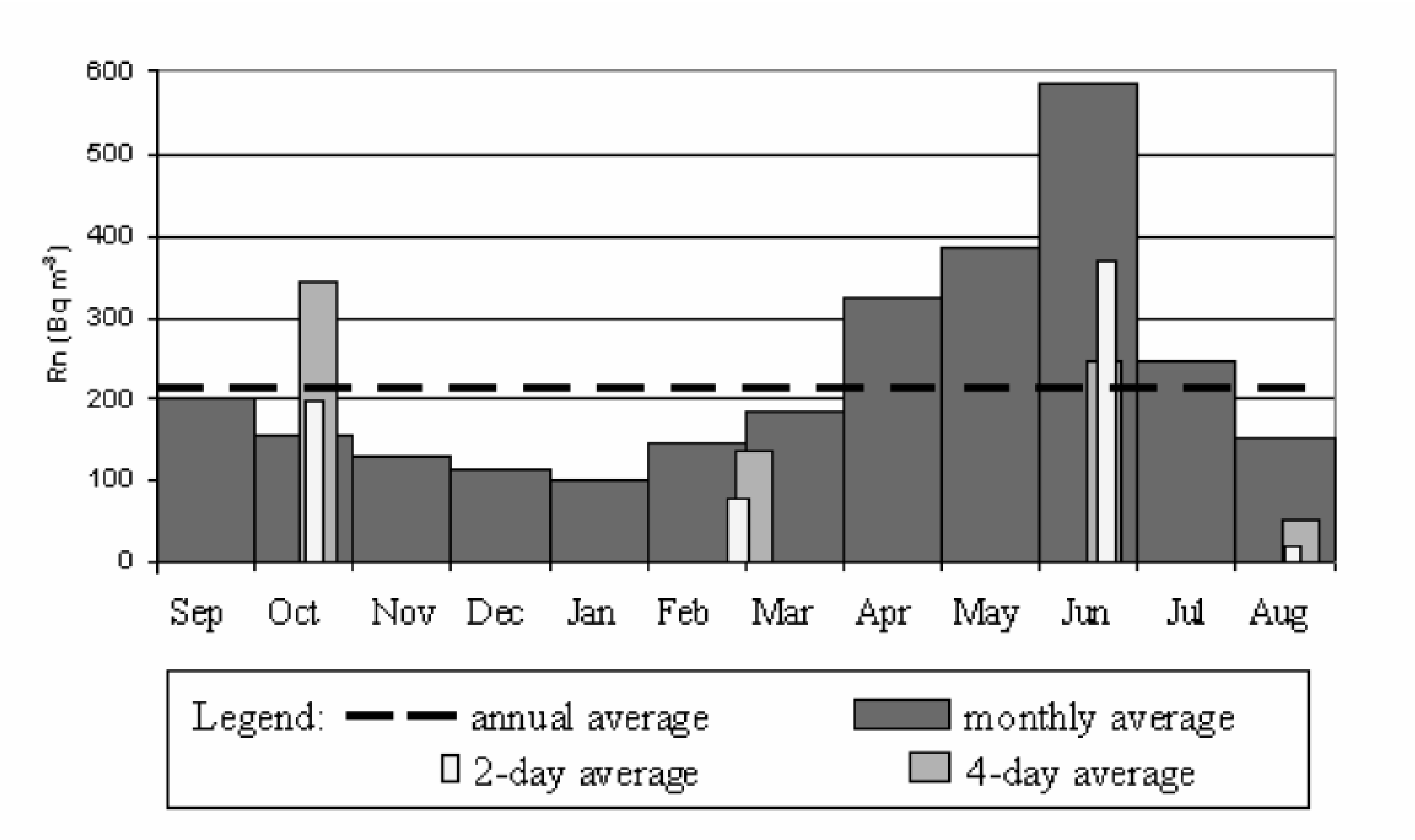
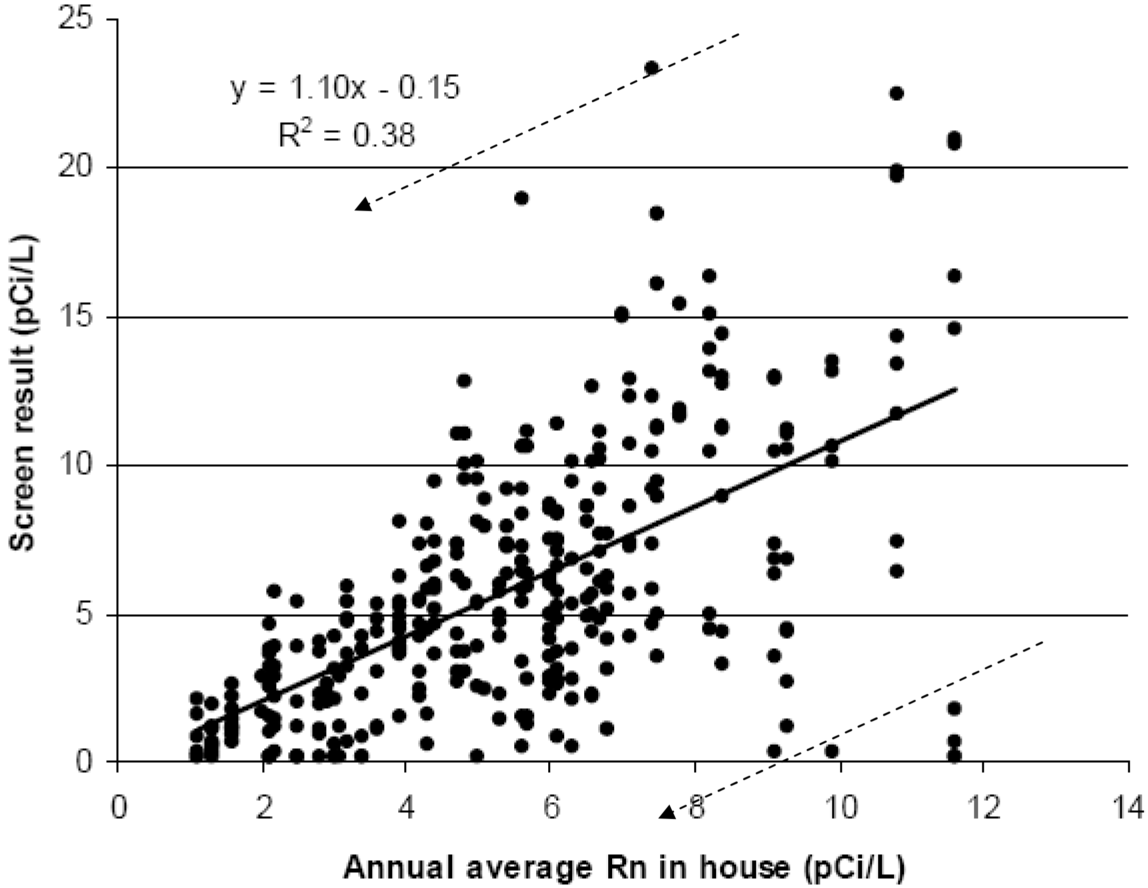


Figure 2. Sample Temporal survey results from measurement site SD3A0.

Steck 2005



Note – vast majority (~95%) w/n +/- 3x of annual avg.

(see added dashed lines)

Figure 3. Linear regression between ST screening measurements and the annual average radon in the house (one high radon house is not shown) in the Temporal survey

Steck 2005

- Longer duration samples are less variable

Table 3. Comparative variations of different averaging periods and operating conditions at the primary measurement site in the Temporal survey

Measurement Type: House conditions	COV about the annual average[1]
Two day: closed	76%
Four day: closed	70%
Monthly: normal	40%
Seasonal (90 day) average: normal	25%
Semi-annual average: normal	17%

[1] Corrected for instrumental variation

COV = Coefficient of Variation = (std. dev. / mean)

Year-to-year variations

Martz et al. 1991

- 40 CO residences yr-long ATD* since 1984
  - Mean COV 25%
    - i.e., if average, a result of 4 pCi/L could be 3 or 5
  - Individual home COV from 7.7% to 51%
- Zhang et al. (2007)
  - Coefficient of Variation (COV) for variation
    - Median COV – year 1 to 2 = 12%
    - Median COV – year 1 to 3 = 19%
-

* ATD = Alpha Track Detector

Steck 2009 (& Steck, 2007 AARST)
Annual Averages over 2 Decades

- Year-long measurements have been: “gold std”
    - 1700 year-long measurements (1983-2000) in 98 MN homes
  - Median <u>of the group </u>showed :
    - Little year-to-year variation
    - No persistent temporal trends
  - Year-to-year variation in the <u>individual sites</u> showed :
    - Median COV of 26%
    - Range from 3 to 110% (some w/ persistent trends + & -)
  - Assoc. w/ Climate, exposure to Wind & Conc.
  - Assoc. w/ modifications to House Structure & HVAC

Steck 2007

American Association of Radon Scientists and Technologists 2007 Proceedings
Of the 2007 AARST International Symposium Jacksonville, FL, 2008©AARST

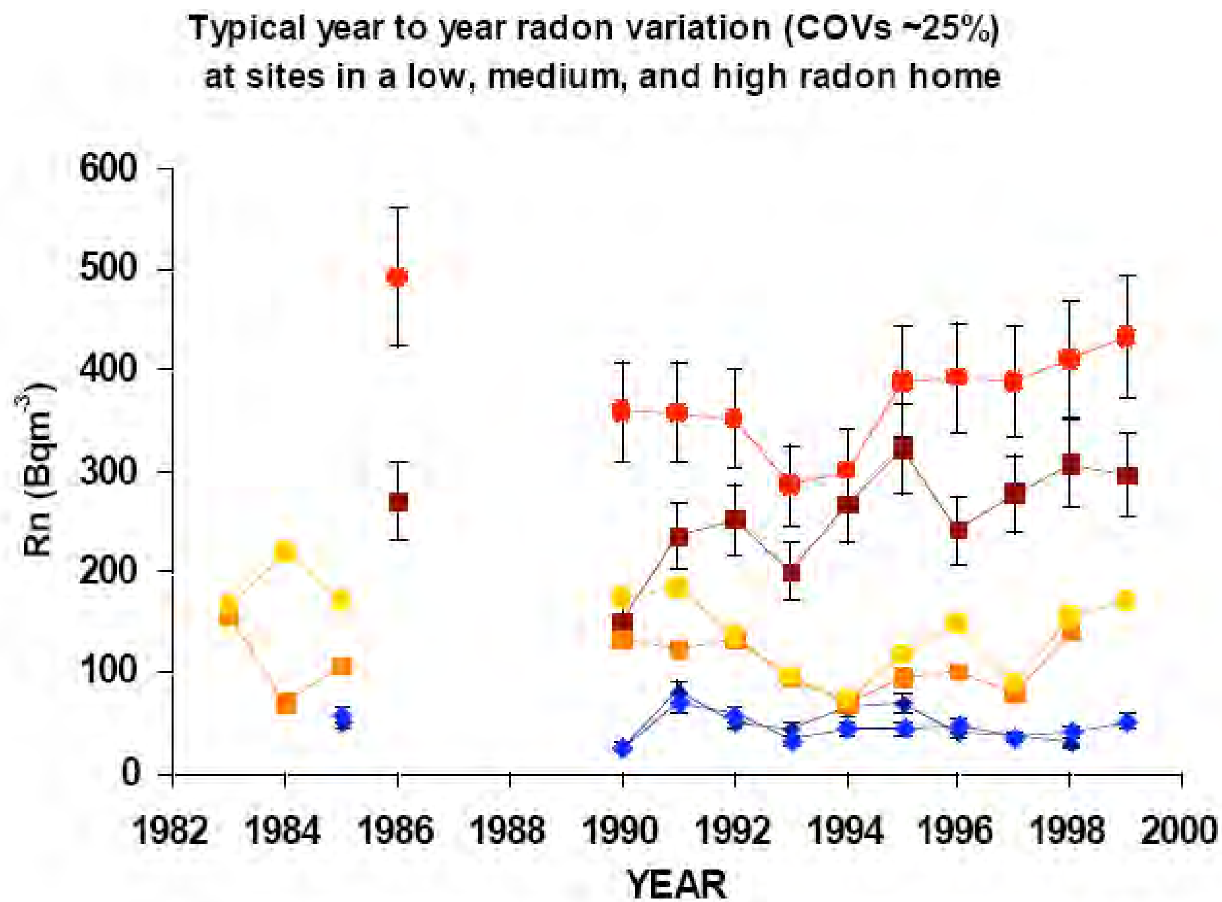


Figure 2 Sample year-to-year radon changes in houses without persistent trends and median COVs.

http://www.aarst.org/proceedings/2007/8-SteckYTYRnvariation07.pdf

Are chemicals more predictable?

- Little evidence to indicate chemical vapor intrusion is any more predictable than radon.

- In fact, some features suggest chemical VI prediction may be even more difficult; such as:
  - 1) Spatial heterogeneity of the chemical contaminant source zones (e.g., large areas with 0 conc.) at a given point in time,
  - 2) Temporally varying spatial distribution of a mobile (e.g., vapor or groundwater plume migration) source term
  - 3) Temporally varying source concentration at a given point over time (10x pulses in GW)
  - 4) Transient (non-equilibrium) nature following a release (prior to equilibrium being established (USEPA 2008b)) not to surface yet
  - 5) Variable degradation rates – Less to More than constant for Rn
  - 6) Chemicals influenced by geology deeper than 3 Rn ½ lifes

A Hypothesis & Challenge: Protective Decisions can be made w/ short-term Indoor Air samples

- Considering the EPA-sponsored US-wide work
  - White 1994
- and more recent radon (e.g., year-to-year) and chemical VI work
  - Folkes 2009
- Along with considerations of possible chemical complexities (1-6)

- Reasonably protective and defensible science-based decisions can be made if:
  - the <u>mean</u> of two or more short-term ($\geq$ 2-day) indoor air samples is less than 1/3* of screening criteria
    - (i.e., 95% of screening data expected w/n 3x of long-term values)
    - *Adjustment factor could be reduced w/ science-based justifications
  - The evidence from Radon studies appear to support this;
  - Can it be demonstrated to be reliable for chemical VI?

The Waterloo Membrane Sampler™ for Monitoring VOC Vapor Concentrations

Cost-effective indoor and outdoor air evaluation for human health risk assessment

SiREM is pleased to announce the availability of a new passive sampler, the Waterloo Membrane Sampler™ (WMS™) for monitoring VOC vapor concentrations. Originally developed at the University of Waterloo, this sampler has undergone three years of applied research and is now available for commercial use.

The design incorporates a polydimethylsiloxane (PDMS) membrane across the face of a vial filled with a sorbent medium. VOC vapors partition into and permeate through the membrane. The sorbent then traps the vapors, and the mass of each compound is determined by GC/MS. The uptake rate has been experimentally measured for many common VOCs and can easily be calculated for other compounds because it is directly proportional to the retention index, a property that is readily available in the scientific literature. Thus, you can use the WMS™ sampler to measure time-weighted average concentrations for virtually any VOC.

The WMS™ sampler offers several advantages compared to conventional air sampling methods:

- Lower cost
- Simpler sampling protocols
- Lower reporting limits without a premium price
- Longer time-integrated samples
- Very small size (discrete to deploy, and easy to ship)

Furthermore, the WMS™ sampler provides significant benefits compared to other quantitative passive air samplers:

- Predictable uptake rates for less common compounds
- Ability to measure Total Petroleum Hydrocarbons/Gasoline Range Organics
- Minimal effect of moisture (good for subsurface monitoring)
- Insensitive to wind velocity (good for outdoor and vent-pipe monitoring)
- Ability to modify uptake rate to avoid starvation effect
- Small diameter (easy to put in vent-pipes or sub-slab probes)
- Competitive pricing

The WMS™ sampler is available through SiREM and analytical services are provided by Air Toxics Ltd. (Folsom, CA), a specialty air laboratory.

Sampler in a glass overpack for shipping

Sampler being deployed for sub-slab gas sampling

Sampler deployed in a vapor off-gassing pipe

For more information, contact:
Hester Groenevelt at
1-866-251-1747 ext. 252
or hgroenevelt@siremlab.com

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The Waterloo Membrane Sampler™ for Monitoring VOC Vapor Concentrations

Equation 1

$$C = \frac{M}{t \times k^{-1}}$$

Equation 2

$$t = \frac{M_{LOQ}}{C_{RL} \times k^{-1}}$$

Close-up of membrane

For more information, contact:

Hester Groenevelt at
1-866-251-1747 ext. 252
or hgroenevelt@siremlab.com

Determination of Concentration

Concentrations in the sampled air are calculated according to Equation 1, where:

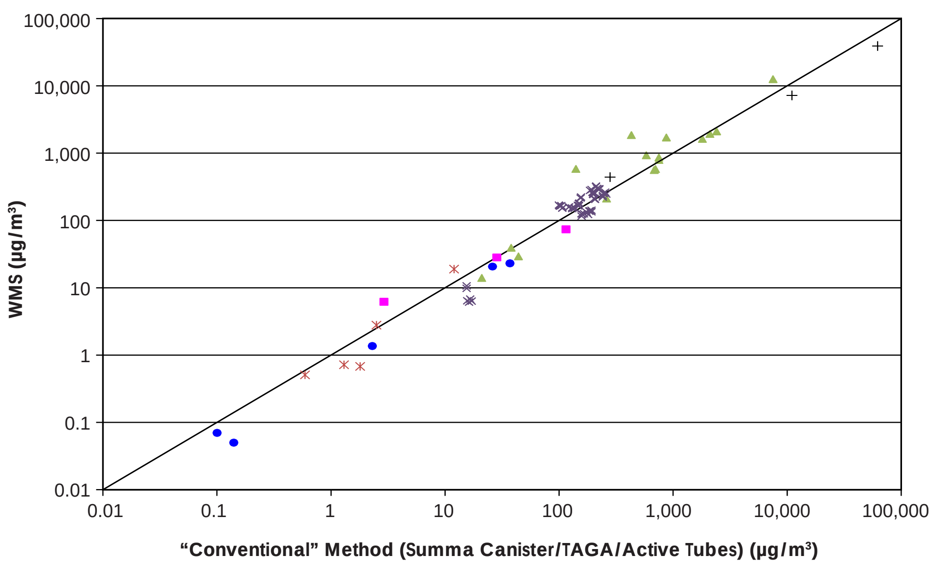
C = concentration in sampled air (μg/m^3)
M = mass on sampler (picograms)
t = sampling time (min)
k^{-1} = known analyte-specific uptake rate (mL/min)

Reporting Limits and Sampling Time

The sampling time required to meet a desired reporting limit can be calculated using Equation 2, where:

t = sampling time required to achieve the reporting limit (min)
M_{LOQ} = minimum mass on sampler that analytical method can measure (picograms)
C_{RL} = reporting limit required (μg/m^3)
k^{-1} = known analyte-specific uptake rate (mL/min)

Comparison of WMS™ VOC Results to Conventional Methods



Note: analytes are a variety of chlorinated volatile organic compounds

The WMS™ sampler results compare very well to "conventional" sampling results (Summa canisters, US EPA's Trace Atmospheric Gas Analysis (TAGA) unit, or active sorbent tubes) over at least six orders of magnitude.

References

Seethapathy, S., T. Górecki and X. Li, 2008. "Passive sampling in Environmental Analysis", *Journal of Chromatography A*, 1184, pp. 234–253.

Górecki, T. and J. Namiesnik, 2002. "Passive Sampling", *Trends in Analytical Chemistry*, 21(4), pp. 276-291.